PB88-113691

REMEDIAL ACTION COSTING PROCEDURES MANUAL

JRB Associates
McLean, VA

Oct 87

U.S. Department of Commerce
National Technical Information Service
NTIS

PB88-113691

EPA/600/8-87/049
October 1987

REMEDIAL ACTION COSTING PROCEDURES MANUAL

by

Brian Burgher,[1] Mike Culpepper,[2] and Werner Zieger[1]

EPA Contract 68-03-3113

EPA Project Officer
Douglas Ammon

[1]JRB Associates, McLean, VA 22102

[2]CH_2M Hill, Atlanta, GA 30339

OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE
OFFICE OF EMERGENCY AND REMEDIAL RESPONSE
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

HAZARDOUS WASTE ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/600/8-87/049		PB88 113691/AS

4. TITLE AND SUBTITLE	5. REPORT DATE
Remedial Action Costing Procedures Manual	October 1987
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Brian Burgher[1], Mike Culpepper[2] and Werner Zieger[1] 1 JRB Associates 2 CH_2M Hill	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
[1]JRB Associates 8400 Westpark Drive McLean, VA 22102 [2]CH_2M Hill Atlanta, GA 30339	11. CONTRACT/GRANT NO. 68-03-3113

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Hazardous Waste Engineering Research Laboratory Office of Research & Development U.S. Environmental Protection Agency Cincinnati, OH 45268	Final, 1/85-9/86 14. SPONSORING AGENCY CODE EPA/600/12

15. SUPPLEMENTARY NOTES

Project Officers: Douglas Ammon 513/569-7876
Bruce Clemens N/A

16. ABSTRACT

This manual provides specific procedures for the cost estimating and economic analysis steps required for preparing engineering cost estimates for selecting remedial action alternatives in response to the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (40 CFR 300). This manual is designed to be used in conjunction with EPA's manual entitled Guidance on Feasibility Studies Under CERCLA (1985). The audience for this manual includes EPA Regional Project Officers, remedial investigation/feasibility study contractors, and state and local remedial action personnel and other Federal agencies. Detailed procedures are provided for generating estimated capital and annual operating costs, calculating annual costs and present worth for each remedial action alternative, and performing sensitivity analyses of the cost estimates to determine the impact of changes to various cost input parameters. Worksheets are provided to assist the user in developing the feasibility cost analyses. An example cost analysis is provided to illustrate these procedures.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to public	unclassified	68
	20. SECURITY CLASS (This page)	22. PRICE
	unclassified	PC A04/MF A01

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

NOTICE

The information in this document has been funded, wholly or in part, by the United States Environmental Protection Agency under Contract No. 68-03-3113 to JRB Associates. It has been subject to the Agency's peer and administrative review and has been approved for publication as an EPA document.

This handbook is intended to present procedures for preparing detailed feasibility cost estimates for remedial action alternatives.

FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the nation's environment and its effect on the health and welfare of the American people. The thousands of uncontrolled hazardous waste sites across the Nation pose a potentially significant threat to the quality of our natural environment. The complexity of that environment and the interplay of its components require concentrated and integrated programs to adequately address this serious problem.

Under the authorities of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), the Office of Emergency and Remedial Response and the Office of Waste Programs Enforcement are responsible for overseeing the development and implementation of the Government's program for response to uncontrolled releases of hazardous substances. These responses ensure that threats to public health, welfare, or the environment are appropriately addressed through the effective management of CERCLA's enforcement and funding authorities. The Hazardous Waste Engineering Laboratory develops new and improved technologies and systems to prevent, treat, and manage hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution.

This document is a cooperative effort between the Office of Solid Waste and Emergency Response and the Office of Research and Development. It is one of a series of reports being published to implement CERCLA, otherwise known as Superfund. These reports provide an array of information necessary for compliance with the National Contingency Plan (NCP, 47 FR 31180, July 16, 1982), including: guidance for remedial investigation and feasibility studies, guidance for exposure assessments, analytical and engineering methods and procedures, research reports, technical manuals, toxicological and engineering data bases, and other reference documents pertinent to Superfund.

This document provides guidance for the preparation of detailed feasibility cost estimates of remedial action alternatives required under the revised NCP. It provides project managers and decision makers in government and industry with procedures for developing and evaluating cost estimates for alternative remedial responses to the uncontrolled releases of hazardous substances. In conjunction with other publications in this series, it will assist in meeting the national goal of adequately protecting public health, welfare, and the environment.

ABSTRACT

This manual is intended to provide specific procedures for the cost estimating and economic analysis steps required for preparing engineering cost estimates for selecting remedial action alternatives in response to the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (40 CFR 300). This manual is designed to be used in conjunction with EPA's manual entitled Guidance on Feasibility Studies Under CERCLA (1985). The anticipated audience for this manual includes EPA Regional Project Officers, remedial investigation/feasibility study contractors, and state and local remedial action personnel and other Federal agencies.

Remedial action costing is divided into three phases: (1) an initial site response assessment plan phase; (2) an alternative development and cost screening phase; and (3) a detailed cost estimation phase for feasibility studies. The remedial action cost estimation process begins with the initial site response assessment which is a plan for undertaking remedial actions at a hazardous waste site. The plan summarizes existing site information, addresses the types of remedial activities required at the site, recommends initial remedial measures, addresses community relations concerns at the site, and estimates remedial response budget and schedule requirements.

The feasibility study cost estimation process begins with the development of specific alternatives based on general response actions identified in the remedial investigation to address site contamination problems. EPA's manual entitled "Remedial Action Cost Compendium" is used along with other sources referenced in this document to estimate screening costs for the various available remedial action alternatives. These estimates are used to eliminate those alternatives whose costs are order-of-magnitude (i.e., more than 10 times) greater than competing alternatives yet do not provide commensurate environmental and public health benefits.

Alternatives that pass the screening cost process undergo detailed cost analyses to provide the decisionmaker with information for selecting the most cost-effective remedial alternative. Detailed procedures are provided for generating estimated capital and annual operating costs, calculating annual costs and present worth for each remedial action alternative, and performing sensitivity analyses of the cost estimates to determine the impact of changes to various cost input parameters. Worksheets are provided to assist the user in developing the feasibility cost analyses. An example cost analysis is provided to illustrate these procedures.

TABLE OF CONTENTS

	Page
Notice	ii
Foreword	iii
Abstract	iv
Figures	vii
Tables	viii
Acknowledgements	ix
1. INTRODUCTION	1-1
2. INITIAL SITE PLANNING COSTING	2-1
2.1 INITIAL SITE PLANNING REPORT FORMAT	2-1
2.2 INITIAL SITE PLANNING DATA	2-4
2.3 FACTORS AFFECTING COSTS	2-10
2.4 UPDATING COST DATA	2-10
2.5 ADDITIONAL SOURCES OF COST INFORMATION	2-10
3. FEASIBILITY STUDY COSTING	3-1
3.1 OVERVIEW OF FEASIBILITY STUDY COSTING	3-1
3.1.1 Screening Cost Analysis	3-1
3.1.2 Feasibility Cost Analysis	3-2
3.2 COST ESTIMATION	3-2
3.2.1 Capital Costs	3-7
3.2.2 Annual Operating Costs	3-11
3.2.3 Sources of Cost Information	3-15
3.2.4 Cost Updating	3-18
3.3 ECONOMIC ANALYSIS	3-19
3.3.1 Capital Costs	3-19
3.3.2 Annual Costs	3-19
3.3.3 Present Worth Analysis	3-21

TABLE OF CONTENTS (Continued)

		Page
3.3.4	Presentation Cost Analysis Results.	3-22
3.4	SENSITIVITY ANALYSIS	3-25
3.5	EXAMPLE.	3-26
3.5.1	Capital Costs	3-29
3.5.2	Annual Operating Costs.	3-31
3.5.3	Annual Costs.	3-31
3.5.4	Present Worth Analysis.	3-31
3.5.5	Sensitivity Analysis.	3-31
REFERENCES	. . . . .	R-1

FIGURES

		Page
3-1	Feasibility Study Alternative Development and Screening Process.	3-3
3-2	Remedial Action Detailed Feasibility Costing Process	3-4
3-3	Worksheet 1: Capital Cost	3-12
3-4	Worksheet 2: Basis of Capital Cost Estimate	3-13
3-5	Worksheet 3: Annual Operating Costs	3-16
3-6	Worksheet 4: Cost Analysis Worksheet.	3-20
3-7	Worksheet 5: Summary of Cost Analysis	3-24
3-8	Worksheet 6: Sensitivity Factors.	3-27
3-9	Worksheet 7: Summary of Sensitivity Analysis.	3-28
3-10	Worksheet 1: Capital Cost (Example)	3-30
3-11	Worksheet 3: Annual Operating Costs (Example)	3-32
3-12	Worksheet 4: Cost Analysis Worksheet.	3-33
3-13	Worksheet 5: Summary of Cost Analysis (Example)	3-34
3-14	Worksheet 6: Sensitivity Factors (Example).	3-36
3-15	Worksheet 7: Summary of Sensitivity Analysis (Example). . . .	3-37

TABLES

		Page
2-1	Remedial Investigation/Remedial Measures (Costs)	2-6
3-1	Criteria for Distinguishing Between Remedial Action and Operation and Maintenance (O&M) Clean-Up Response Activities.	3-6
3-2	Discount Factors	3-23

ACKNOWLEDGEMENTS

This document was prepared for the Office of Emergency and Remedial Response and the Hazardous Waste Engineering Research Laboratory in partial fulfillment of Contract No. 68-03-3113, by JRB Associates. Mr. Douglas Ammon of the Hazardous Waste Engineering Research Laboratory (HWERL) and Mr. Bruce Clemens[1] of the Office of Emergency and Remedial Response (OERR) were the EPA co-Project Officers. Mr. Robert Cochran and Ms. Virginia Hodge were successive project managers with JRB Associates.

This report is the compilation of the efforts of several major contributors, which include:

Brian Burgher	JRB Associates
Mike Culpepper	CH2M Hill
Werner Zieger	JRB Associates

Preparation of this guidance document was aided greatly by the constructive criticisms of the following reviewers:

Mr. Douglas Ammon	U.S. EPA/HWERL
Mr. Bruce Clemens	U.S. EPA/OERR
Mr. Bill Hansen	U.S. EPA/OERR
Mr. Jim Jowett	U.S. EPA/OERR
Mr. Jim Lounsbury	U.S. EPA/OERR
Mr. Steve Smith	U.S. EPA/OERR
Mr. Jim Spatarella	U.S. EPA/OERR[2]
Mr. Rick Stanford	U.S. EPA/OERR[2]
Mr. Roger Wetzel	JRB Associates
Ms. Nancy Willis	U.S. EPA/OERR

We also approciate the assistance extended by the American Association of Cost Engineers.

---

[1] Currently with Clean Sites, Inc.
[2] Currently with PRC

CHAPTER 1

INTRODUCTION

As the number and scope of remedial actions at uncontrolled hazardous waste disposal sites increase, there is a corresponding need for standard procedures for preparing engineering cost estimates for proposed remedial solutions. The National Contingency Plan (NCP) outlines a general approach for conducting remediation at Superfund sites. The purpose of this manual is to provide specific procedures for the cost estimating and economic analysis steps required for the various remedial action planning phases. These phases are:

- Preparing an initial assessment of remedial action alternatives to establish a general cost for the remedial investigation/feasibility process and initial remedial measures
- Screening remedial action alternatives during feasibility analysis to eliminate those alternatives for which the costs are substantially greater than other alternatives and yet do not provide a commensurate public health or environmental benefit
- Preparing detailed cost estimates for feasibility studies to aid in selecting a remedial action alternative.

This manual presents procedures and provides worksheets to accomplish the cost analysis objectives of the above phases. The guidance presented has been developed for generalized conditions at uncontrolled hazardous waste disposal sites. The user should modify these procedures where necessary to accommodate site-specific conditions.

The anticipated audience for this document includes those persons responsible for Superfund remedial actions: EPA Regional Project Officers, remedial investigation/feasibility study contractors, state and local remedial action personnel, and other Federal agencies. This manual should also be useful to those involved in planning state- and private-lead and voluntary actions, particularly to demonstrate to the public and other interested parties that the selection of a remedial action alternative was conducted according to EPA approved procedures.

Chapter 2 of this manual addresses initial site planning cost estimating. Site response assessment costing is important, because it sets the tone for the remedial investigation and feasibility study, and gives a rough estimate of the level of effort and funding necessary to address site problems under Superfund. It is a fairly straightforward procedure requiring minimal time and effort to complete as will be evident in the discussion in Chapter 2. It should be noted that these initial costs will be superceded by costs derived during the feasibility study process.

Chapter 3 describes how costs are developed for the remedial alternative screening process and the more detailed feasibility analysis. A series of worksheets are included to simplify the cost estimating exercises and to provide a format for presentation of data. An example is given at the end of Chapter 3 to illustrate the feasibility cost analysis and the use of these worksheets.

CHAPTER 2

INITIAL SITE PLANNING COST ESTIMATING

A site response assessment is a plan for undertaking remedial actions at a hazardous waste site. It summarizes existing site information, addresses the types of remedial activities required at the site, recommends initial remedial measures (IRM's), addresses community relations concerns at the site, and estimates budget and schedule requirements for subsequent remedial response activities. The EPA uses the site response assessment to plan future site response actions and to provide general direction to the future activities associated with the remedial investigation and feasibility study (RI/FS) process.

Because data available at the site response assessment stage are very general any costs derived for this plan will be of an order-of-magnitude or lesser level of accuracy. This accuracy has been defined as a final construction cost which will fall within the range of +50% to -30% of the cost estimated at the site response assessment stage.

The purpose of this section is to define the steps of the site response assessment process and offer guidelines as to how costs for each of these steps may be derived. With this data the reader should be able to:

- Construct a site response assessment report outline and identify areas which require estimating.
- Assign order-of-magnitude costs to the applicable sections of the site response assessment report format.
- Determine total order-of-magnitude costs for site RI/FS activities and remedial alternatives available at the site response assessment stage.

The site response assessment report generally follows the outline shown below but should be adapted to the specific site response assessment needs.

2.1 Initial Site Response Assessment Report Format

The format for the Initial Site Response Assessment Report is as follows:

1.0 INTRODUCTION

- 1.1 Purpose of Report
- 1.2 Site Location
- 1.3 General Approach
- 1.4 Limitations and Disputes Including Community Relations
- 1.5 Initial Remedial Measures
- 1.6 Remedial Investigations
- 1.7 Source Control Remedial Actions (if applicable)
- 1.8 Off-site Remedial Actions (if applicable)
- 1.9 Cost/Schedule

Note: The executive summary contains an explanation of the nature of a site response assessment, along with the conclusions developed as part of the response assessment. The introduction may also contain a cost/schedule table relating to the recommended RI/FS and remedial activities. The introduction should not reference other sections of the site response assessment and should stand alone as an independent summation.

2.0 DATA EVALUATION

- 2.1 Objective
- 2.2 Background
  - 2.2.1 Site Location and Description
  - 2.2.2 Site History
  - 2.2.3 Chronology Including Permit and Regulatory Action History
- 2.3 Hazardous Materials Characterization
  - 2.3.1 Hazardous Material Sources
  - 2.3.2 Types and Quantities of Hazardous Material
- 2.4 Environmental Setting
  - 2.4.1 Physiography
  - 2.4.2 Geology
  - 2.4.3 Hydrology
  - 2.4.4 Geohydrology
  - 2.4.5 Air Quality
  - 2.4.6 Ecology
  - 2.4.7 Socioeconomics
- 2.5 Assessment of Potential Impacts
  - 2.5.1 Public Health and Safety
  - 2.5.2 Environment
  - 2.5.3 Socioeconomics
- 2.6 Data Limitations/Sources

Note: Since the generation of new data is not within the scope of site response assessment development, only available information is used in this section. If no information is available on air quality, for example, that fact is to be noted as a data gap if it is determined air quality data are required to characterize the site.

3.0 REMEDIAL ACTIVITIES

3.1 Remedial Action Plan

- 3.1.1 Overall Approach to Site
- 3.1.2 Master Site Schedule
- 3.1.3 Sequencing, Timing, Correlations of Projects

3.2 Initial Remedial Measures

- 3.2.1 Objectives
- 3.2.2 Recommended Initial Measures (if any) with Justification
- 3.2.3 Estimated Cost/Schedule/ Deliverables
- 3.2.4 Community Relations Activities
- 3.2.5 Data Limitations/Needs

3.3 Remedial Investigation/Feasibility Study (assuming the remedial investigation/feasibility study is to be the first recommended remedial action. This section is to be the basis for the RI/FS work plan.)

- 3.3.1 Objectives
- 3.3.2 Scope of Work (Task Descriptions - including community relations implementation)
- 3.3.3 Remedial Investigation/Feasibility Study Estimated Cost/ Schedule/Deliverables
- 3.3.4 Data Limitations/Needs

3.4 Source Control Remedial Actions

- 3.4.1 Objectives
- 3.4.2 Remedial Action Alternatives
- 3.4.3 Order-of-Magnitude Level Costs/Schedule
- 3.4.4 Data Limitations/Needs

3.5 Off-site Remedial Actions

- 3.5.1 Objective
- 3.5.2 Remedial Action Alternatives
- 3.5.3 Order-of-Magnitude Level Costs/Schedule
- 3.5.4 Data Limitations/Needs

Note: This effort centers primarily on the Remedial Investigation and Feasibility Study activities. Source control and off-site remedial actions are not to be developed if there is insufficient information to do so.

4.0 COMMUNITY RELATIONS ASSESSMENT

4.1 Background
4.1.1 History of Community Relations Activities
4.1.2 Community Relations Issues and Actions

4.2 Objectives and Techniques
4.2.1 Objectives
4.2.2 Techniques

4.3 Schedule of Activities

5.0 SITE VISIT HEALTH AND SAFETY PLAN

2.2 Initial Site Planning Data

As shown in the initial site planning report format, cost estimates are required for various sections of the site response assessment. These sections of the initial site planning report format are shown in Table 2-1. This table is broken down into different sections as described below:

- Task - Lists the major categories for which costs must be determined. These categories correspond to assessment report format sections 3.0 through 4.0 of the format for assessing remedial responses at sites.

- Subtask - Shows major cost categories within each Task.

- Scope - Defines Subtasks into cost line items.

- Low Costs - Offers guidelines for determining the minimum labor and expenses necessary to accomplish a particular Task. (Actual numbers shown on Table 2-1 are considered minimum for each Task.)

- High Costs - Offer guidelines for determining the maximum labor and expenses necessary to accomplish a particular Task. (Actual numbers shown on Table 2-1 are considered maximum for each Task.)

- Comments - Offer clarifying, additional or limiting information relating to a particular Task.

It should be noted that one area of Table 2-1 not specifically detailed on the site assessment response format is "III RM (Remedial Measures) Costs". It is the goal of the EPA to determine at the assessment stage an order-of-magnitude construction cost estimate for each recommended alternative (i.e., costs in a range of +50% to -30%). These costs will be used to evaluate alternatives and to budget future work. Costs for the recommended alternative should be determined by applying costs from the Remedial Action Cost Compendium (1) to the list of remedial measures to determine project construction costs.

2.3 Factors Affecting Costs

Costs and level of effort shown in Table 2-1 should be considered as a guideline only with costs for each individual site tailored to fit the characteristics of that site. It should be mentioned however that the guideline costs shown in Table 2-1 are the recommended low and high costs for personnel protection levels D and B, respectively. Costs for Level A sites should be examined individually on a site by site basis because productivity and type of waste material usually require special measures for these sites. Additional guidance on estimating the effects of health and safety requirements on site response costs can be found in "Completed Scenario Bid Packages--Costs of Remedial Actions of Uncontrolled Hazardous Waste Sites," U.S. EPA, In Print. Guidance has also been compiled in the "Compendium of Cost of Remedial Technology at Waste Sites" U.S. EPA, In Print, on the effects of a variety of site characteristics on the costs of remedial actions. The compendium includes both historical cost data and recently developed estimates on remedial action technologies. Tables are contained within this document which will assist the user in organizing component costs for mobilization, demobilization, site preparation, and remedial activities with respect to work safety cost components.

2.4 Updating Cost Data

Costs shown on Table 2-1 should be updated by applying the indices from the Remedial Action Cost Compendium. Labor and expense costs used in this section should include allowances for overhead, profit, and contingencies. Copies of the worksheets should be included with the initial site planning report as cost support data. Worksheets and tables are available from several sources. The sources and their uses are referenced in Section 3.2.4.

2.5 Additional Sources of Cost Information

Various cost sources may be used when determining site assessment response costs. The following are sources listed in recommended order of importance:

- Remedial Action Cost Compendium - The Cost Compendium represents a compilation of remedial action costs from hazardous waste projects performed nationwide over the past several years. Costs included here offer a wide range of hazardous waste cost data from which to adapt to a specific project scope of work.

- Other Remedial Actions - These costs may include data from other remedial projects conducted in the vicinity of the site and not included in the compendium. These costs could include cost estimates of projects as well as actual project costs.

TABLE 2-1.

REMEDIAL INVESTIGATION/REMEDIAL MEASURE COSTS

Task	Subtask	LOW COSTS Scope	People (p)	Days (d)	Labor $	Expenses
I Workplan Preparation & Initial organization						
	1.1 Organization & admin.	o Assign teams, meet with EPA & State o Gather accessible background data from EPA & State	3	2	$2,400	$200/p/d = $1,200
	1.2 Initial site visit	o Prepare site visit health & safety plan	1	3	$1,200	-
		o Perform site visit	3	2	$2,400	$240/p/d = $1,440
	1.3 Draft & final workplan		2	5	$4,000	-
	1.4 Project QA plan		1	3	$1,200	-
II IRM Plan	2. Prepare initial remedial measures plan	o Assess needs for IRM o Develop plan for IRM o Determine technical requirements & costs related to these tasks o Submit draft & final plan o Perform alternative analysis	2	2	$1,600	-
III IRM Costs	3.1 Develop list of remedial measures	o Expand list developed in IRM Plan	2	5	$4,000	$500
	3.2 Determine order of magnitude cost estimate for construction activities	o Apply list of remedial measures to costs from Remedial Action Cost Compendium to determine project construction costs	2	5	$4,000	$1,000

*Labor based on $50/manhour; it may be necessary to adjust these appropriately to reflect regional variation in labor rates.

Note: Numbers with a "+" (e.g., $3,000+) indicate costs are a minimum and could ultimately be higher.

		HIGH COSTS					
Total $	Comments	People (p)	Days (d)	Labor $	Expenses	Total $	Comments
		5	2	$4,000	$300/p/d = $3,000	$7,000	NOTE: WP must also be set up to address changes in scope based on incoming data as the investigation progresses
$1,600	Includes travel						
		2	5	$4,000	-	$8,000	No initial entry by FIT
$1,200	Assume 1st time entry completed by TAT	5	2	$4,000	$500/p/d = $5,000	$9,000	Level B, includes travel
$1,840	Level C, includes travel	4	30	$48,000	-	$48,000	Same as low costs
$4,000	Includes initial plans for all subsequent tasks	2	5	$4,000	-	$4,000	Same as low costs
$1,200	Includes site data management plan and procedures	4	10	$16,000	-	$16,000	Numerous & complicated IRM (alternative water supply, drum removal, etc.)
$1,600	Limited IRM (fences, etc.). Implementation costs are function of actions special to the site						
$8,000	--					$16,000	
$4,500	Total cost of the remedial measure will consist of construction costs as well as non-construction costs such as planning & engineering						
$5,000							

(continued)

TABLE 2-1.

REMEDIAL INVESTIGATION/REMEDIAL MEASURE COSTS

Task	Subtask	Scope	LOW COSTS People (p)	Days (d)	Labor $	Expenses
IV H&S Plan & Implementation	4.1 Develop Health & Safety Plan	o Assess risks at site in detail o Review baseline data o Present detailed H&S Plan to EPA	2	3	$2,400	-
	4.2 Establish mobile onsite facility	o Acquire separate decontamination facilities & separate trailers	-	-	-	$600/m shower $250/m office $100/m utilities + $1,000 hookup
V Additional Record		o Obtain other information not readily available for previous efforts o Conduct personal interviews	2	4	$3,200	$1,000
VI Community Relations	6.1 Develop Community Relations	o Prepare community relations program	2	5	$4,000	-
		o Public meeting preparation and attendance	5	5	$1,200	
		o On-going public	5	5	$1,000	
		o Advertising			$ 500	
		o Travel			$1,000	
VII Plan & Perform Topographic Survey	7.1 Prepare site topographic survey plan, select subs	o Prepare bid documents o Evaluate MBE, SBE, LSA subcontractors o Select subcontractors o Receive and evaluate subcontractors' workplan	1	5	$2,000	$1,000

*Labor based on $50/manhour; it may be necessary to adjust these appropriately to reflect regional variation in labor rates.

Note: Numbers with a "+" (e.g., $3,000+) indicate costs are a minimum and could ultimately be higher.

HIGH COSTS							
Total $	Comments	People (p)	Days (d)	Labor $	Expenses	Total $	Comments
$2,400		2	14	$11,200	$4,000	$15,200	Level B - "Bad Site"
$2,000+	Electricity, water easily accessible	-	-		$800/m shower $50/m office $100/m utilities +$2,000 hookup	$6,000+	Office and decon trailer, utilities (including water)- costs assume power
$4,200	Note that this task will always be necessary. It should be done concurrent with WP development	2	7	$5,600	$1,000	$6,600	--
$4,000		2	10	$8,000	-	$8,000	--
$1,200		2	5	$4,000		$4,000	--
$1,000		1	10	$4,000		$4,000	--
$500					$1,500	$1,500	--
$1,000					$5,000	$5,000	--
$3,000		2	4	$3,200	$1,500	$4,700	--

(continued)

TABLE 2-1.

REMEDIAL INVESTIGATION/REMEDIAL MEASURE COSTS (Continued)

Task	Subtask	Scope	LOW COSTS People (p)	Days (d)	Labor $	Expenses
	7.2 Perform topographic survey (subcontractor). Prepare topographic survey map	o Aerial survey o Tie-in evaluations manually, including areas of interest (storm drains, etc.) o Scale and contour determined in plan	-	-	-	0-25 acre = $5,000 25-50 acre = $7,000 50-75 acre = $10,000 >75 acres = $130/acre
VIII Plan & Perform Geophysical Survey	8.1 Prepare Geophysical Survey Plan, select subcontractors	o Re-evaluate previous data o Investigate use of: - seismic reflection (SR) - electrical resistivity - ground penetrating radar (GPR) o Prepare bid documents o Evaluate subcontractors o Select subcontractor o Receive & evaluate subcontraactor workplan	1	8	$3,200	$1,000
	8.2 Subcontractor perform geophysical survey	o As outlined in plan o Includes report by subcontractor o Monitor subcontractor o Resistivity o Magnetometer o GPR o Seismic reflection o SR interpretation o GPR interpretation	-	-	-	$5,000 min.; $1,000/acre $400/acre $300/acre $1,000-2,000/d $750-1,200/d $300-500/1000 ft $250-400/crew-day
	8.3 Prepare report	o Develop report for EPA	1	5	$2,000	$500

*Labor based on $50/manhour; it may be necessary to adjust these appropriately to reflect regional variation in labor rates.

Note: Numbers with a "+" (e.g., $3,000+) indicate costs are a minimum and could ultimately be higher.

Total $	Comments	People (p)	Days (d)	Labor $	Expenses	Total $	Comments
$5,000 $7,500 $1,000 $1,250	Minimum. These costs are sensitive to site to site conditions and should be computed on a project-by-project basis	-	-	-	0-25 acre = $6,000 25-60 acre = $8,500 50-75 acre = $12,000 >75 acre = $150/acre	-	$6,000 minimum. These costs are sensitive to site conditions and should be computed on a project-by-project basis
$4,200	Simple site; shallow investigation required-no drums, etc.; no GPR useage; little electromagnetic interference (buried cables, overhead wires, etc.); relatively simple geological strata. Level C or D site Level C or D site	1	20	$8,000	$3,000	$11,000	Very difficult site; requiring all 4 investigative methods for a big area (>40 acres) with difficult terrain & high potential for electromagnetic problems. Level B H&S
$5,000+	Based on simple site, requiring shallow seismic & ER. Note on-site survey will be done as well as the area surrounding the site. Costs are based on actual size of the site. Level C site	-	-	-	$10,000 min. $3,000/acre	$10,000+	Level B site, same comments for subtask 7.1. Per acre method may overestimate costs for large sites. For other methods of costing, consult technical assistance group.
$2,500	--	2	5	$4,000	$1,000	$5000	If sub does not develop report or site very detailed.

(continued)

TABLE 2-1.

REMEDIAL INVESTIGATION/REMEDIAL MEASURE COSTS (Continued)

			LOW COSTS			
Task	Subtask	Scope	People (p)	Days (d)	Labor $	Expenses
IX Conduct Environmental Investigation & Sampling Program	9.1 Hydrogeological investigation (monitor well installation, GW & soils sampling & analysis)	o Prepare hydrogeological plan. Select subcontractors (as in Task 6)	1	10	$4,000	-
	Note: Divided into sub subtasks (you may want to separate Task VIII into several tasks)	o Have subcontractor perform tasks, prime contractor monitors sub-contractor	-	-	-	$30/ft; $1,000 min.
		o Sample existing water supply wells, sample monitoring wells	1	1	$3,600	$300/well + $500/p expenses, minimum of $2,000
		o Characterize groundwater (GC/MS priority pollutants)	-	-	-	-
		o Analyze soil samples taken during well installation for engineering characteristics as well as EP toxicity (including priority pollutant scan)	-	-	-	-
		o Report	2	10	$8,000	-
	9.2 Surface water, leachate, and sediment sampling & analysis	--	3	3	$3,600	$300/sample/d, $500/p/d expenses, $2,500 min.; for analysis, see Task 8.1.4

*Labor based on $50/manhour; it may be necessary to adjust these appropriately to reflect regional variation in labor rates.

Note: Numbers with a "+" (e.g., $3,000+) indicate costs are a minimum and could ultimately be higher.

		HIGH COSTS					
Total $	Comments	People (p)	Days (d)	Labor $	Expenses	Total $	Comments
$4,000		1	20	$8,000	-	$8,000	--
$1,000+	Shallow wells, easy access; drilling through sand, clay; Level C protection; PVC pipe	-	-	-	$60/ft; $3,000 minimum	$3,000+	Complex geology, crossprotection of aquifer required deeper than 200', difficult access, drilling through rock, stainless steel pipe, Level B protection
		4	4	$6,400	$400/well + $500/p expenses; $3,600 minimum	$10,000 QC paperwork	4 deep wells per day, highly contaminated,
$5,600+	Based on 3 people, sampling maximum of 4 wells per day, lodging & food. Note: paperwork is extensive						
-	Analytical costs vary with the type of labs used (EPA contract or private). Contact CH2M						
-	Hill labs for actual costs						
		2	20	$16,000	-	$16,000	--
		4	4	$6,400	$400/sample, $500/p expenses; $3,400 minimum	$9,800+	Large area, difficult terrain (swamp, etc.)
$8,000	--						
$6,100+	3 people taking 4 samples per day. Note: paperwork is extensive						

(continued)

TABLE 2-1.

REMEDIAL INVESTIGATION/REMEDIAL MEASURE COSTS (Continued)

			LOW COSTS			
Task	Subtask	Scope	People (p)	Days (d)	Labor $	Expenses
	9.3 Air quality sampling & analysis	--	2	2	$1,200	$160/d for equipment; for analysis, see Task 8.1.4
QC	9.4 Onsite waste sampling	o Lagoons	3	2	$2,400	$570/d for equipment; for analysis see Task 8.1.4
		o Drums & Barrels	3	4	$4,800	$560/d for equipment; for analysis see Task 8.1.4
	9.5 Bioassay Costs	-	2	4	$3,200	$200/d for equipment
X Develop Site Assessment Report	10.1 Prepare site assessment report	-	2	20	$16,000	-
	10.2 Site evaluation meeting	With EPA, State	2	2	$1,600	$500/p = $1,000
	10.3 Revise site assessment report	-	2	10	$8,000	-

*Labor based on $50/manhour; it may be necessary to adjust these appropriately to reflect regional variation in labor rates.

Note: Numbers with a "+" (e.g., $3,000+) indicate costs are a minimum and could ultimately be higher.

HIGH COSTS							
Total $	Comments	People (p)	Days (d)	Labor $	Expenses	Total $	Comments
$1,520+	Equipment includes wind-speed directional instrument w/recorder, high volume sampler, OVA (1 unit organic vapor entrapment)	1	2	$800	$430d/for equipment	$1,660+	3 OVA units, more high volume samplers
$1,540+	3 sample locations (surface, mid, sludge); boat sample; shipping, QC paperwork, Level C	5	5	$10,000	$570/d	$12,850+	--
$7,040+	Low to medium hazard, Level B. Equipment includes drum openers (manual), sample tubes; sampling 3 drums/hr with a 6 hr decon.	4	10	$16,000	$740/d	$23,400+	High hazard, Level B or A, remote drum puncturing apparatus
$4,000	--	3	8	$9,600	$1,200	$10,800	--
$16,000	--	2	30	$24,000	-	$24,000	--
$2,600	--	2	4	$3,200	$600/p = $1,200	$4,400	--
$8,000	--	2	15	$12,000	-	$12,000	--

- Standard Cost Guides - Standard cost guides include any number of available books published by R.S. Means Co., Inc.; Dodge Guide; Richardson Engineering Services, Inc.; or others. Because productivity at a typical hazardous waste site varies considerably from the norm, costs from these standard guides should be adjusted accordingly to compensate for the difference.

CHAPTER 3

FEASIBILITY STUDY COSTING

This chapter describes standard procedures for preparing cost estimates for remedial action alternatives being evaluated during feasibility analysis. Initial site planning cost estimating efforts, discussed previously in Chapter 2, are based solely on existing data and are performed to provide general cost data associated with RI/FS activities, Remedial Removal measures, and remedial alternatives. Feasibility study cost estimating is aimed solely at providing remedial alternative costs using information collected during the remedial investigation. The following sections provide an overview of the costing process for both screening and detailed feasibility analysis of alternatives (Section 3.1); guidance on preparing capital and annual operating cost estimates (Section 3.2); procedures for economic analysis (Section 3.3); guidance on the use of sensitivity analysis (Section 3.4); and an example illustrating these cost analysis procedures (Section 3.5). Additionally, worksheets are provided to assist the user to estimate, analyze, and present costs for remedial action alternatives.

3.1 Overview of Feasibility Study Costing

Two sets of cost estimates are generated within the overall feasibility study process. Initially, order-of-magnitude costs are generated to screen out disproportionately expensive alternatives. Subsequently, feasibility costs are developed and used in selecting an alternative. While the basic procedures for generating these cost estimates are essentially identical, the user should achieve a greater level of accuracy for the feasibility costs through the use of more extensive data sources and a more detailed preliminary design based on information available from the remedial investigation. At least one alternative should be costed that complies with Federal hazardous substances and waste management regulations and standards.

3.1.1 Screening Cost Analysis

The objective of the screening cost analysis is to eliminate alternatives that have costs an order-of-magnitude greater than those of other alternatives but do not provide greater environmental or public health benefits or greater

reliability. Such order-of-magnitude evaluations or comparisons are defined as those values that are ten times or more as large as other values (9).

Screening cost estimates are generated during the alternative development and screening process depicted in Figure 3-1. These estimates are used to eliminate those alternatives whose costs are significantly greater than competing alternatives yet do not provide commensurate environmental and public health benefits.

The user should primarily rely on "Remedial Action Cost Compendium" to estimate screening costs along with the other sources referenced in that document. The accuracy of the costs should be in the +100% to -50% range. The time and level of effort to prepare these costs should not normally exceed one week and 80 man-hours, respectively.

3.1.2 Feasibility Cost Analysis

Following initial screening, a manageable number of remedial action alternatives should remain for the feasibility cost analysis. Cost estimates for feasibility cost analysis are intended to provide a measure of the total resource costs over time associated with any given remedial alternative.

The development of cost estimates for remedial action alternatives involves the following steps which are also illustrated in Figure 3-2:

1. Estimation of Costs - estimate capital and annual operating and maintenance costs for each remedial action alternative.

2. Present Worth Analysis - using estimated costs, calculate annual costs and present worth for each remedial action alternative.

3. Sensitivity Analysis - evaluate the sensitivity of cost estimates to changes in key parameters.

4. Input to Alternatives Analysis - summarize input data to the alternatives analysis for selection of a remedial action alternative.

Feasibility analysis costs are typically derived from a number of sources, including vendor estimates, and should be accurate within a range of +50 to -30 percent; this accuracy range represents an order-of-magnitude for cost estimating as defined by the American Association of Cost Engineers. The time and level of effort to complete this analysis should not normally exceed two weeks and 120 man-hours, respectively.

Figure 3-1. Feasibility Study Alternative Development and Screening Process

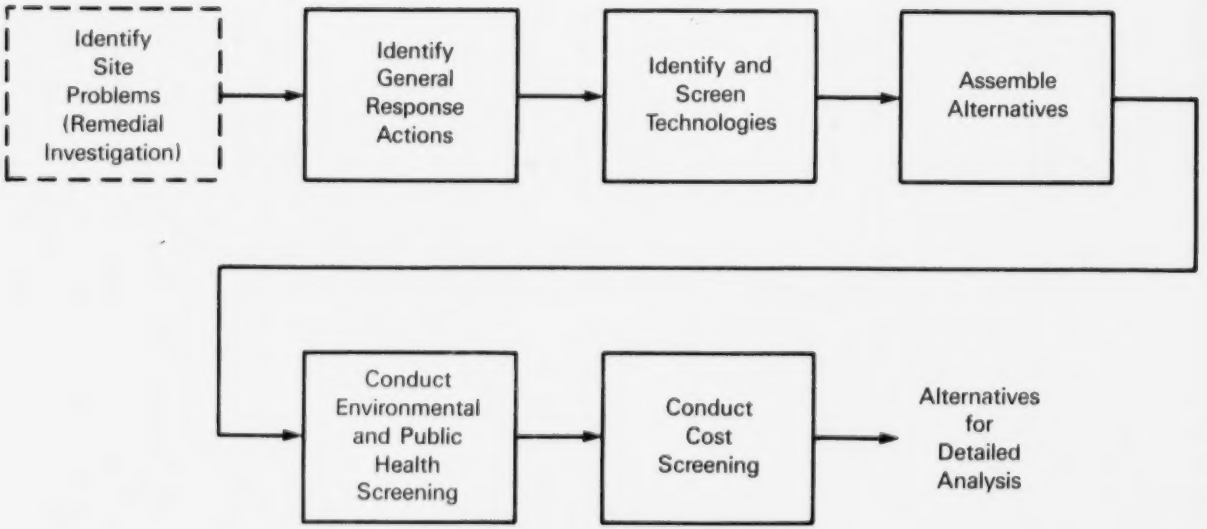
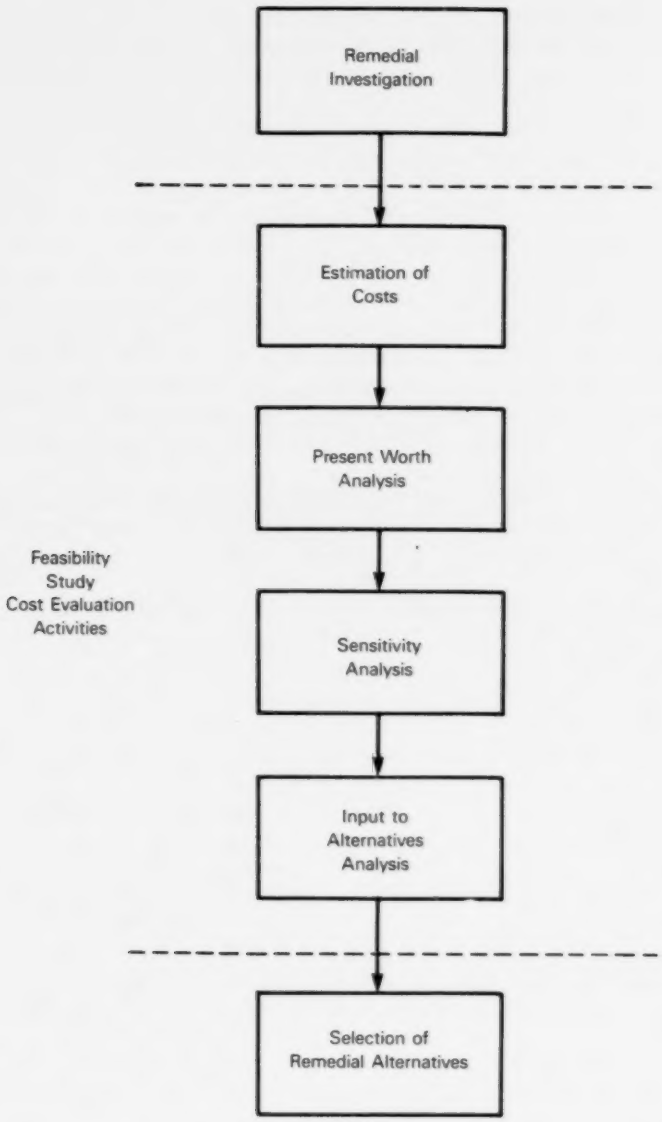

Identify Site Problems (Remedial Investigation)
Identify General Response Actions
Identify and Screen Technologies
Assemble Alternatives
Conduct Environmental and Public Health Screening
Conduct Cost Screening
Alternatives for Detailed Analysis

Figure 3-2. Feasibility Study Cost Evaluation Process



3.2 Cost Estimation

This section describes procedures for estimating capital and annual operating costs for remedial action alternatives. Sunk costs are not to be included in this evaluation; sunk costs include investments or commitments made prior to or concurrent with remedial action planning. The various cost components that should be considered and sources for cost data are identified. Worksheets are provided to assist the user in organizing and presenting the cost data for each alternative and can be used for both screening and detailed costing. The reader is also referred to such books as Principles of Engineering Economy by Eugene L. Grant and W. Grant Ireson, and Economics of Water Resource Planning by Douglas James and Robert Lee, for comprehensive discussions of the procedures presented in this section.

Federal construction programs have traditionally distinguished between capital costs and operation and maintenance (O&M) costs. Federal participation in public works projects such as highways and wastewater treatment plants has been limited to construction, involving the funding of a major share of project capital costs. Following construction, costs for operation and maintenance are the responsibility of state or local government. However, the distinction between the construction and operation phases of a Superfund cleanup response is not as easily made. The completion of construction will not achieve public health or environmental protection in many instances. Such protection may be afforded only after operation of the remedial technology for a period of time. Nevertheless, a distinction must be made in order to determine which costs are eligible for Superfund.

EPA has divided Superfund response activities into two phases: (1) remedial action, and (2) post-closure or operation and maintenance (O&M). Only costs incurred under the remedial action phase will be fund eligible.

EPA defines a remedial action as consisting of those activities required to prevent or mitigate the migration into the environment of hazardous waste released at an uncontrolled disposal site. It may include activities usually considered to be O&M in situations where construction, by itself, will not achieve health or environmental protection. However, a remedial action will have a limited duration and a well-defined end-point.

The post-closure or O&M phase occurs after completion of the remedial action and includes those activities necessary to continue stopping migration of releases of hazardous waste into the environment. Post-closure will typically control area-wide off-site contamination and will require long term or indefinite activities.

Table 3-1 summarizes the criteria for distinguishing between the remedial action and O&M phases of a Superfund cleanup response.

While the distinction between the remedial action and O&M phases of a cleanup is important for determining fund eligibility, it should not be a factor in feasibility cost analysis. The purpose here is to develop

TABLE 3-1. CRITERIA FOR DISTINGUISHING BETWEEN REMEDIAL ACTION AND OPERATION AND MAINTENANCE (O&M) CLEAN-UP RESPONSE ACTIVITIES

Remedial Actions	O&M
o Controls contamination at or near the source of release (source control measures)	o Controls area-wide and off-site contamination (off-site measures)
o Results in the mitigation of a release	o Required to stop or control continued migration
o Action is of limited duration (generally less than 4 years)	o Requires long-term or indefinite activities
o Contaminant levels can be identified to mark the end of the remedial action	o Activities required to maintain the effectiveness following completion of the remedial action
o Results in a significant protection to public health or the environment	

comparative life-cycle cost information for the remedial action alternatives under consideration for use in the alternative selection process. These alternatives include both the remedial action and O&M phases. Thus, for purposes of feasibility costing, the user should observe the conventional distinctions between capital and O&M costs, where capital and initial construction costs are analogous.

3.2.1 Capital Costs

Capital costs are those expenditures required to initiate and install a remedial action. They are exclusive of costs required to maintain or operate the action throughout its lifetime. Capital costs include only those expenditures that are initially incurred to develop and incorporate a remedial action (e.g., installation of a cap or slurry trench) and major capital expenditures anticipated in future years (e.g., replacement of a cap or slurry trench). This differentiation between capital costs and operation and maintenance costs does not necessarily reflect a determination as to the fund eligibility of the costs.

Capital costs consist of direct and indirect costs. Direct costs are those expenditures necessary for installation of remedial actions. Indirect costs include expenditures for engineering, financial, supervision and other necessary services that are not part of actual installation activities.

The user should consider both direct and indirect costs in the development of capital costs of remedial actions, regardless of level of accuracy required. This section presents guidance for estimating capital costs for two levels of accuracy: screening remedial action alternatives and feasibility study cost estimates. The procedures used to develop cost estimates--screening and feasibility study--are similar. They differ only in the level of detail of the alternative preliminary design and sources used to develop cost components and hence their level of accuracy.

3.2.1.1 Direct Capital Costs

Direct costs include equipment, labor and materials necessary for installation or construction of remedial actions. These include costs for:

- Remedial action construction
- Component equipment
- Land and site development
- Buildings and services
- Relocation of affected population where appropriate
- Disposal costs of waste materials.

Each of these individual direct capital cost components are discussed in the following sections.

The user should consider the impact of on-site health and safety precautions on construction and installation costs. Many of these precautions can significantly increase costs by decreasing productivity. Guidance is provided in the "Remedial Action Cost Compendium" (1) for estimating the impact of different levels of health and safety requirements at remedial action sites.

Remedial Action Construction Costs--

Construction costs, one of the major components of direct capital costs, are expenditures for equipment, labor and materials required to install a remedial action. Construction activities would include:

- Site modifications such as installation of slurry walls, cap system, and run-off controls; excavation of contaminated materials; and site preparation for remedial action equipment
- Installation of remedial action equipment such as construction of leachate collection, pumping systems, and treatment systems
- Installation of testing and monitoring equipment such as soil borings and construction of monitoring wells
- Surface controls (e.g., grading and erosion control).

Construction costs are typically available for individual activities (e.g., excavation and backfill) and include itemized equipment labor and material components. Labor costs will include all fringe benefits, worker's compensation and contractor fees. The user should be careful that these costs reflect reduced labor productivity resulting from the health and safety precautions necessary during construction of the remedial action alternative.

Component Equipment Costs--

Equipment costs are those expenditures required for equipment necessary to conduct a major remedial action. Major equipment expenditures are generally required for remedial actions involving on-going treatment operations such as groundwater treatment and waste destruction. Equipment typically required for remedial action operations includes:

- Pumping systems
- Treatment systems
- Monitoring and sampling equipment.

Land and Site Development Costs--

Land-related expenses consist of both the purchase of new land and the development of existing property. New land purchases are typically not required but may be necessary for sites which have small land areas, limited access or are located in nearby population centers. Property development will commonly be needed to develop a remedial action. Components of property development include:

- Development of access roads
- Incorporation of access control (e.g., gates, fences)
- Site preparation for equipment and buildings.

Land-related expenses are typically a small part of total capital costs, but may be significant in some cases.

Buildings and Services Costs--

Installation of remedial actions may require construction of temporary and permanent buildings as well as establishing support services. Building costs may include both process structures (e.g., piping supports, concrete pads) and non-process structures (e.g., laboratories, control buildings, temporary engineering and supervision buildings). Service costs may include temporary or permanent utility connections for these facilities, including water and sewer lines, electric substations and connections, and energy sources. These costs include equipment, labor, and materials needed for construction or installation.

Relocation of Affected Population Costs--

Costs for relocating people living near a site property may be necessary in some remedial actions. These costs may include temporary or permanent accommodations for nearby residents, moving allocations, and other necessary associated costs. Assistance for relocation costs is available on a case-by-case basis from the Federal Emergency Management Administration (FEMA).

Disposal of Waste Material Costs--

Disposal of waste materials generated during the course of remedial actions must be considered when estimating capital costs. Waste materials such as waste treatment residuals, soil excavation materials, and waste

excavation materials must be properly disposed in off site disposal areas. The costs associated with transportation and off site disposal are included in capital costs.

3.2.1.2 Indirect Capital Costs

Indirect capital costs consist of engineering, financial, supervision and other services necessary to carry-out a remedial action. They are not incurred as part of actual remedial actions but are ancillary to direct or construction costs. Indirect capital costs include costs for design, engineering, and contingency allowances.

Each of these components are discussed in the following sections.

Engineering Expenses--

Design and construction of remedial actions involves engineering expenses incurred by internal staff administration and outside contractor support. Engineering expenses include costs for:

- o Administration and supervision
- o Design and development
- o Drafting
- o Monitoring and testing
- o Project and cost engineering.

Typically engineering expenses are in the range of 7 to 15 percent of total direct capital costs (2). Nevertheless, certain sites will require additional resources for legal fees, obtaining license/permits, and start-up and shake-down of equipment.

Expenses are typically required as part of site remedial actions for legal fees and administrative and technical personnel necessary to obtain licenses and permits. Construction permits and temporary or long-term operating permits, such as building, electrical connection and water supply permits may be required from Federal, state and local jurisdictions to complete a remedial action. Similarly, legal advice may be necessary to obtain licenses or negotiate construction and operating contracts. Legal and license/permit costs are typically in the range of 1 to 5 percent of total remedial action costs (2).

The user should include costs for system start-up and shake-down to achieve design operating parameters for remedial actions involving long-term operating activities, such as treatment operations. Costs include those for operation, testing equipment and materials required for remedial action equipment, "debugging" and testing, operator training, and initial field

monitoring. Such costs are considered separate from contingency allowances as they are expected as part of remedial action start-up. Start-up and shake-down costs can be expected to involve 5 to 20 percent of total capital costs where system operations are involved (2, 3). Start-up costs are not required for remedial actions, such as excavation and site modification actions, which do not include operating equipment.

Contingency Allowances--

Contingency allowances are added to total capital costs to account for unforeseen circumstances which result in additional costs. Contingencies may include adverse weather conditions, strikes by material suppliers, and inadequate site characterization (particularly subsurface). Contingency allowances typically fall in a range from 15 to 25 percent of total capital costs.

3.2.1.3 Sources of Capital Costs

Data sources for preparing capital cost estimates include the Remedial Action Cost Compendium (1), equipment vendors, construction companies, similar projects, and standard costing references. These sources are discussed in Section 3.2.3.

3.2.1.4 Updating Costs

Costs are often available based on data several years old and must be updated to a common year. Procedures for updating capital costs are provided in Section 3.2.4.

3.2.1.5 Presentation of Capital Costs

The user should present remedial action alternative capital costs in a consistent format which displays all cost estimates and their source in an organized manner. Worksheets 1 and 2 are provided in Figures 3-3 and 3-4 for presenting capital costs. Each cost component should be itemized, where possible.

3.2.2 Operation and Maintenance (O&M) Costs

Operation and maintenance costs are those post-construction/installation costs necessary to ensure continued effectiveness of a remedial action. This section presents procedures for both screening and feasibility cost analysis.

FIGURE 3-3. WORKSHEET 1: CAPITAL COST

Cost Component	Cost Estimate	Basis of Estimate	Year Incurred
DIRECT CAPITAL COSTS			
1. Construction Costs			
a. Equipment			
b. Labor			
c. Materials			
Subtotal			
2. Equipment Costs			
__ Installed			
__ Purchased			
3. Land and Site Development			
a. Equipment			
b. Labor			
c. Materials			
Subtotal			
4. Buildings and Services			
a. Equipment			
b. Labor			
c. Materials			
Subtotal			
5. Relocation Costs			
Subtotal			
6. Disposal Costs			
Subtotal			
TOTAL DIRECT COSTS			
INDIRECT CAPITAL COSTS			
1. Engineering and Design			
2. Contingency Allowance			
3. Other Indirect Costs			
a. Legal fees			
b. License/permit Costs			
c. Start-up & Shake-down			
Subtotal			
TOTAL INDIRECT COSTS			
TOTAL CAPITAL COSTS			

FIGURE 3-4.

WORKSHEET 2: BASIS OF CAPITAL COST ESTIMATE*

COST ITEM: _____ COST COMPONENT: _____

BASIS: _____

CALCULATION/SOURCE: _____

*Complete for each capital cost component as necessary.

3.2.2.1 Estimating O&M Costs

In order to estimate O&M costs, the user should identify the cost components for each remedial action alternative, identify sources and methods for developing cost estimates, and, where necessary, update estimates to the current year.

The post-construction/installation activities necessary to ensure continued effectiveness of a remedial action may involve the following cost components:

- Operating Labor - This includes all wages, salaries, training, overhead, and fringe benefits associated with the labor needed for post-construction operations. The user should identify the labor requirements by skill categories for each remedial action alternative.

- Maintenance Materials and Labor - This includes the costs for labor, parts, and other materials required to perform routine maintenance of facilities and equipment associated with a remedial action alternative.

- Auxiliary Materials and Energy - This includes such items as chemicals and electricity needed for plant operations, water and sewer service, and fuel costs.

- Purchased Services - This includes such items as sampling costs, laboratory fees, and other professional services for which the need can be predicted.

- Administrative Costs - This includes all costs associated with administration of remedial action operation and maintenance not included under other categories such as labor overhead.

- Insurance, Taxes and Licenses - This includes such items as: liability and sudden and accidental insurance; real estate taxes on purchased land or right-of-way (for private-lead actions); licensing fees for certain technologies; and permit renewal and reporting costs.

- Maintenance Reserve and Contingency Costs - This includes annual payments into escrow funds to cover anticipated replacement or rebuilding of equipment and any large unanticipated O&M costs, respectively (for private lease actions).

- Other Costs - This includes all other items which do not fit into any of the above categories.

The limited time and resources available for developing screening cost estimates--in addition to the objectives with respect to accuracy and detail--dictate that the sources used be restricted to the "Remedial Actions Cost Compendium" (1) and other readily available sources such as Initial Planning for Remedial Measures.

The level of accuracy needed for the detailed feasibility analysis requires that the O&M cost estimates be based on site-specific information. The following sources should be consulted in addition to those used for screening:

- o Equipment vendors
- o Estimates for similar projects
- o Actual experience at similar projects
- o Standard costing guidance references.

These sources are discussed in more detail in Section 3.2.3.

O&M cost estimates based on data a year or more old should be updated to the current year using an appropriate cost index. Procedures for updating cost are discussed in Section 3.2.4.

3.2.2.2 Presentation of Operation and Maintenance Costs

The user should summarize O&M cost estimates on Worksheet 3 (Figure 3-5) to facilitate calculation of annual costs and present worth in subsequent steps. The user should identify each component, enter the annual cost estimate and note the basis for the estimate in the appropriate columns. The remaining columns should be used to indicate whether the cost is expected to occur annually or less frequently and the year or period over which a cost is expected to occur. For example, for a remedial action with a twenty-year planned life, a cost that occurs annually over the entire life would be recorded as "annually" under "frequency" and "1-20" under "year/period." Furthermore a major maintenance item which is required every five years would be recorded as "5, 10, 15" under "year/period" (presumably, this maintenance would not be performed in the final year).

The completed worksheet now contains annual operating cost information necessary to calculate annual costs and present worth.

3.2.3 Sources of Cost Information

The user should rely primarily on the "Remedial Action Cost Compendium" (1) plus other readily available sources, where appropriate, for screening cost estimates. Additional sources, including vendor estimates, should be used for detailed feasibility analysis to achieve the desired level of accuracy. Nevertheless, the accuracy of cost estimates depend more on the level of detail of the preliminary design of a remedial action alternative than on the sources of cost information used. The remedial investigation should provide sufficient site information to permit the necessary refinement of preliminary remedial action designs for the detailed feasibility analysis.

FIGURE 3-5.

WORKSHEET 3: ANNUAL OPERATING COSTS

Cost Component Estimate($)	Basis of Estimate	Frequency	Year/ Period
O & M Costs			
1. Operating Labor a. _____ b. _____ c. _____			
2. Maintenance Materials and Labor a. _____ b. _____ c. _____			
3. Auxiliary Materials and Labor a. _____ b. _____ c. _____			
4. Purchased Services a. _____ b. _____ c. _____			
5. Administration			
6. Insurance, Taxes, Licenses a. _____ b. _____ c. _____			
7. Maintenance Reserve and Contingency Costs			
8. Other			

The following are the major sources available for estimating remedial action costs:

- o Remedial Action Cost Compendium
- o Vendor estimates
- o Estimates for similar projects
- o Standard costing guidance.

The following sections describe these sources in more detail.

3.2.3.1 Remedial Action Cost Compendium

The major source of cost data for remedial actions is provided by the "Remedial Action Cost Compendium," (1) which is a comprehensive compilation of cost data covering the full range of remedial technologies outlined in the NCP. The costs are based on past remedial actions and generic costs developed where actual remedial action applications do not exist. All costs were updated to the common base year (1983).

3.2.3.2 Vendor Estimates

Based on detailed site and design information, equipment vendors, and construction companies can provide site-specific remedial action construction and equipment costs for capital cost estimates. Construction estimates typically include equipment mobilization, operation and leasing costs, labor costs, and contractor fees.

Equipment vendors can also provide information on the O&M requirements for the equipment they manufacture. Recommended maintenance schedules can provide an indication of maintenance costs, although these are often estimated as a percentage of capital costs. Specifications often provide information on auxiliary materials and energy usage costs.

3.2.3.3 Estimates for Similar Projects

Estimates developed for similar projects--or, preferably, actual experience with such projects--are good sources of capital and O&M cost information. Where necessary, these costs should be updated according to the procedures discussed in Section 3.2.4.

3.2.3.4 Standard Costing Guidance

Construction cost estimates can be developed from standard guidance references, such as the Dodge Guide (5) and Means Guide (4). These sources provide unit costs for a wide variety of construction activities, including those relevant to remedial actions. Estimates using these sources must be adjusted to reflect reduced labor productivity resulting from the health and safety precautions required during construction of a remedial action alternative.

Labor and energy cost information is published by the Bureau of Labor Statistics (U.S. Department of Labor) and U.S. Department of Energy, respectively. These sources are particularly useful for determining regional differences in labor, materials, and energy costs.

In addition to these standard references, cost engineers frequently use estimating factors (based on percentages of other cost items, such as capital costs) to develop O&M cost estimates. Some of the factors typically used include:

- Labor fringe benefits -- 20-30% of wages (4)
- Equipment O&M Costs -- 3-5% of purchase price
- Insurance -- 1% of capital costs (exclusive of environmental impairment liability)
- Reserve fund -- 1% of capital costs.

3.2.4 Cost Updating

Estimates of capital and O&M costs may be based on information that is a year or more old and must be updated to the current (base) year of the remedial action. This can be done using a cost index by means of the following formula:

$$C_n = C_o \left(F_n / F_o \right) \qquad (1)$$

where: C_n = new (updated)cost
C_o = old cost
F_o = current index factor
F_n = index factor corresponding to date of old cost.

3.2.3.4 Standard Costing Guidance

Construction cost estimates can be developed from standard guidance references, such as the Dodge Guide (5) and Means Guide (4). These sources provide unit costs for a wide variety of construction activities, including those relevant to remedial actions. Estimates using these sources must be adjusted to reflect reduced labor productivity resulting from the health and safety precautions required during construction of a remedial action alternative.

Labor and energy cost information is published by the Bureau of Labor Statistics (U.S. Department of Labor) and U.S. Department of Energy, respectively. These sources are particularly useful for determining regional differences in labor, materials, and energy costs.

In addition to these standard references, cost engineers frequently use estimating factors (based on percentages of other cost items, such as capital costs) to develop O&M cost estimates. Some of the factors typically used include:

- Labor fringe benefits -- 20-30% of wages (4)
- Equipment O&M Costs -- 3-5% of purchase price
- Insurance -- 1% of capital costs (exclusive of environmental impairment liability)
- Reserve fund -- 1% of capital costs.

3.2.4 Cost Updating

Estimates of capital and O&M costs may be based on information that is a year or more old and must be updated to the current (base) year of the remedial action. This can be done using a cost index by means of the following formula:

$$C_n = C_o \left(F_n / F_o \right) \qquad (1)$$

where: C_n = new (updated)cost
C_o = old cost
F_n = current index factor
F_o = index factor corresponding to date of old cost.

A variety of indices are available to assist the cost engineer in updating, including:

- Engineering News Record (ENR) Construction Cost Index is generally most appropriate for updating construction capital cost estimates
- Chemical Engineering plant cost and equipment cost indices or the Marshall Stevens Index may be more appropriate where treatment facility costs are to be updated
- Annual operating costs should be updated using American City and County's Municipal Index or the Producer Price Index for Finished Goods published by the U.S. Department of Labor in the Monthly Labor Review.

3.3 Present Worth Analysis

This section presents recommended procedures for evaluating costs over the planned lives of remedial action alternatives. Present worth analysis provides a method of evaluating and comparing costs that occur over different time periods by discounting all future expenditures to the present year.

The user should complete Worksheet 4 (Figure 3-6) to facilitate calculation and presentation of annual costs and present worth analysis for each alternative.

3.3.1 Capital Costs

Initial capital costs should be considered to occur in Year 0. The user should enter the estimate from Worksheet 1 (Figure 3-3) under Year 0 on line 1 of Worksheet 4 (Figure 3-6). For an alternative involving phase construction, the user should enter the capital costs for each phase on line 1 under the year when its implementation is planned. Likewise, the user may include any subsequent major capital expenditures not considered to be routine O&M costs on line 1 under the year in which they are expected to occur.

3.3.2 O&M Costs

O&M costs represent the expenditures necessary to cover all remedial action costs as they occur during each year of the planned life of the action. These costs include any anticipated post-construction capital expenditures in addition to annual O&M costs. The user should enter annual O&M costs in Worksheet 4 (Figure 3-6) using the data from Worksheet 3 (Figure 3-5). O&M costs should be entered on line 2.

FIGURE 3-6. WORKSHEET 4: COST ANALYSIS WORKSHEET

Cost Component	Cost/Year Cost Occurs (Thousands of Dollars)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Capital Costs																
2. O&M Costs																
3. Annual Expenditures, x_t (Sum of Lines 1 and 2)																
4. Discount Factors Annual Discount Rate = __ %																
5. Present Worth (Product of Lines 3 and 4)																

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
1. Capital Costs																
2. O&M Costs																
3. Annual Expenditures, x_t (Sum of Lines 1 and 2)																Total Present Worth ($1000)
4. Discount Factor Annual Discount Rate = __ %																
5. Present Worth (Product of Lines 3 and 4)																

Annual costs are the sum of the capital costs (line 1) and total O&M costs (line 2) for each year of the life of the remedial action. The user should enter this sum on line 3 of the worksheet for each year.

3.3.3 Calculating Present Worth

Present worth analysis is a method of evaluating expenditures that occur over different time periods. The costs for different remedial action alternatives can be compared on the basis of a single figure for each alternative by discounting all costs to a common base year. This single figure -- the present worth or value of a project -- represents the amount of money, which, if invested in the initial year of the remedial action and disbursed as needed, would be sufficient to cover all the costs associated with a remedial action.

Three assumptions are necessary for calculating present worth:

- o Inflation or escalation rate
- o Discount rate
- o Period of performance.

It is recommended that the current Office of Management and Budget (OMB) guidance be followed. OMB Circular No. A-94 (6) specifies that costs in future years should not be escalated to account for general price inflation, except where there is a reasonable basis for predicting differences in the relative escalation of costs (or benefits) associated with the project. Otherwise the analyst should use constant (i.e. base period) dollars. Given the difficulty in forecasting relative price changes over an extended period, it is recommended that the user not attempt such forecasts, except perhaps as part of the sensitivity analysis. OMB currently specifies a discount rate of 10 percent, which represents "the average rate of return on private investment, before taxes and after inflation" (6).

The period over which a remedial action requires maintenance and/or operation (period of performance) is also an important factor in present worth analysis. Remedial action alternatives requiring perpetual care should not be costed beyond thirty years, for the purpose of feasibility analysis. The present worth of costs beyond this period become negligible and have little impact on the total present worth of an alternative. Also, it may be appropriate to consider the salvage value of equipment, buildings, and land at the completion of the remedial action. These benefits should be discounted to the present from the last year of the period of performance.

The present value of expenditures occurring over the life of the remedial action is determined using the following equation:

$$PW = \sum_{t=1}^{t=n} \frac{x_t}{(1+i)^t} \qquad (2)$$

where:

PW = Present worth

x_t = expenditures for the remedial action in year t

i = discount rate (i.e., 10%)

t = year in which expenditure(s) occurs

The user should include initial capital costs occurring in Year 0 in the present worth total with discounted future costs.

Worksheet 4 (Figure 3-6) has been provided to facilitate calculation of the present worth of capital and O&M costs occurring after Year 0. The user should determine the annual expenditure (x_t in the equation above) for each year of the period of performance by adding the capital costs (line 1) and O&M costs (line 2). These figures should be entered on line 3 in Worksheet 4. The user should use the discount factors for a discount rate of 10 percent presented in Table 3-2 to simplify calculations of present worth. (Discount factors for rates other than 10 percent can be calculated using the equation $1/(1+i)^t$, where i is the discount rate and t is the year in which costs occur.) The product of the annual expenditures (line 3) and the discount factor (line 4) for each year represents the present worth of the costs occurring in that year, which should be entered in Line 5. The sum of the present worth values for each year over the period of performance represents the present worth of the alternative's cost.

3.3.4 Presentation of Cost Analysis Results

The user should summarize the results of the present worth analysis on Worksheet 5, presented in Figure 3-7, in order to facilitate comparison of cost information for each alternative. The user should enter the alternatives in the worksheet in order (lowest to highest) of their present worth and enter the present worth and annual expenditures data in the appropriate column for each alternative.

TABLE 3-2. DISCOUNT FACTORS

Plan Year	Discount Rate (%) 10.000
0	1.000
1	0.909
2	0.826
3	0.751
4	0.683
5	0.621
6	0.564
7	0.513
8	0.467
9	0.424
10	0.386
11	0.350
12	0.319
13	0.290
14	0.263
15	0.239
16	0.218
17	0.198
18	0.180
19	0.164
20	0.149
21	0.135
22	0.123
23	0.112
24	0.101
25	0.092
26	0.084
27	0.076
28	0.069
29	0.063
30	0.057

*Factor calculated from $(1/0+i)^t$ where i = discount rate and t = year.

FIGURE 3-7. WORKSHEET 5: SUMMARY OF COST ANALYSIS

Cost Factor		Remedial Action Alternatives/Costs					
		1.	2.	3.	4.	5.	6.
Capital Costs ($): (×1000) Year 0							
Present Worth ($): (×1000)							
Annual Costs ($/Years)	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
	13						
	14						
	15						
	16						
	17						
	18						
	19						
	20						
	21						
	22						
	23						
	24						
	25						
	26						
	27						
	28						
	29						
	30						

3.4 Sensitivity Analysis

The objective of this manual has been to recommend procedures that will yield the most accurate cost estimates possible within given constraints of time and resources. Accuracy is important, because the choice of remedial alternatives rests to a large extent on the cost estimates obtained.

Nevertheless, errors in estimating key variables may have a large effect on the accuracy of the overall cost estimate. Thus, a sensitivity analysis is conducted to assess the effects of variation in specific assumptions associated with the design, implementation, operation, and effective life of a remedial action strategy on the estimated cost of the strategy. These assumptions are based on the accuracy of the data developed during the Remedial Investigation and on predictions of the future behavior of the remedial technology and the economy, and are subject to varying degrees of uncertainty.

Sensitivity analysis is especially concerned with those factors that could bring about a significant change in overall costs with only a small change in the value of the factors. Other factors chosen for analysis should be those for which the value is most uncertain. Results of the analysis can be used to identify "worst case" scenarios and to revise estimates of contingency or reserve funds.

Sensitivity analysis also can be used to optimize the design of a remedial action alternative. This is particularly useful where design parameters are interdependent, such as for treatment plant capacity for treating contaminated groundwater and length of remedial action (period of performance).

The following factors are primary candidates for consideration in conducting sensitivity analysis:

- Effective life of remedial action - If the remedial action alternative relies on a new technology or a technology that has not been tested over a 30-year period, the analysis should consider the possibility that all or a portion of the technology may need to be replaced during the life of the remedial action. In estimating replacement cost, use base period dollars; do not adjust for inflation.

- O&M costs - O & M costs, if required, are likely to represent a substantial portion of total project cost, because they may be repeated each year for as long as 30 years. The major components of O&M cost should, therefore, be considered for examination in the sensitivity analysis.

- Duration of clean-up - The duration of clean-up, or period of performance, is often a key variable (e.g., in actions that require the operation of treatment systems for a period of time based on monitoring results). Various assumptions as to the length of period of performance may be suitable candidates for analysis.

- o Uncertainty regarding site conditions - Even after the conclusion of a remedial investigation, significant uncertainties may exist regarding the extent of clean-up necessitated by site conditions. Examples are the volume of groundwater to be treated, the number of drums to be excavated, the type of materials present, and the treatment/disposal options to be used. Various assumptions regarding such parameters may need to be examined.

- o Inflation - Inflation should not generally be examined under OMB costing guidelines, but it may be considered under two conditions: first, if there is good reason to believe that the future prices of materials or services required by a remedial action alternative will increase at a significantly faster or slower rate than the general level of prices in the economy; or second, if the inflation rate for the area in which the site is located can be expected to vary significantly from the national average.

- o Cost of borrowed capital - In private or state actions the cost of capital may be a major factor in determining the overall cost of a remedial action and may be tested in the sensitivity analysis.

Worksheets 6 and 7 are provided to assist the analyst in conducting a sensitivity analysis. In Worksheet 6 (Figure 3-8), Sensitivity Factor Worksheet, the user should list cost factors to be examined, the reasons why they are to be examined, the range of values to be studied, and the justification for the choice of range.

Worksheet 7 (Figure 3-9), Sensitivity Analysis Summary Worksheet, should be used to present the results of the analysis, for comparative purposes. Prior to completing this worksheet, it is necessary to cost each option over the life of the action using Worksheet 4: Annual Costs and Present Worth Analysis (Figure 3-6).

An example of the sensitivity analysis with completed worksheets is presented in Section 3.5.5 of this report.

3.5 Example

An example remedial action alternative is presented in this section to illustrate the major cost analysis procedures discussed in this chapter. This example is for illustration only and should not be assumed to be an actual remedial action alternative for an existing site.

This example pertains to a landfill from which hazardous waste has migrated into an aquifer used as a potable water supply. This example examines a remedial alternative involving construction of a slurry wall, construction and operation of a groundwater extraction and treatment system to control the contaminated plume, and replacement of drinking water wells which

FIGURE 3-8. WORKSHEET 6: SENSITIVITY FACTORS

Sensitivity Factor	Justification for Consideration	Range	Justification for Range

FIGURE 3-9. WORKSHEET 7: SUMMARY OF SENSITIVITY ANALYSIS

Cost Factor		Baseline Cost	Sensitivity Factor Examined/Results					
Capital Costs ($):								
Present Worth ($):								
Annual Expenditures ($/Years x 1,000)	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16							
	17							
	18							
	19							
	20							
	21							
	22							
	23							
	24							
	25							
	26							
	27							
	28							
	29							
	30							

also requires construction of a water supply transmission main. This alternative is one of several that has passed initial screening and for which feasibility cost estimates must be developed.

3.5.1 Capital Costs

Capital cost estimates were developed using standard cost estimating resources such as equipment vendors, estimates for similar projects, actual experience at similar projects, and standard costing references. The capital cost components of the alternative and their estimated cost are as follows:

- Replace public water supply wells to supply 1.5 million gallons a day (9 wells at 200 foot depth, gravel packed with 24 inch diameter outer casing, and 18 inch diameter inner casing with 18 inch diameter well screen) - $1,417,500
- Provide water supply transmission main (17,000 feet of 42 inch pipe connected to existing 60 inch main) - $2,232,000
- Construct abatement well for control of contaminated plume (one 2 million gallon per day well) - $67,500
- Provide facilities for treating plume (SO_2 gas addition for iron control, air stripping, granular activated carbon adsorption, lime addition and operations building) - $2,637,000
- Provide holding basins for iron settling and an effluent pump station - $423,000
- Construct force main for discharge of effluent from treatment facility to nearby creek (30 inch diameter) - $198,000
- Construct a slurry wall to surround the landfill area (130 feet depth) - $2,478,600
- Engineering and contingencies (25% of the subtotal of other capital costs) - $2,363,400
- Disposal of waste materials - $90,000.

The total estimated capital cost is $11,907,000. Figure 3-10 presents a summary of these costs using Worksheet 1, Capital Cost (Figure 3-3).

FIGURE 3-10. WORKSHEET 1: CAPITAL COST (EXAMPLE)

Cost Component	Cost Estimate	Basis of Estimate	Year Incurred
DIRECT CAPITAL COSTS			
1. Construction Costs			
a. Equipment	2,250,000		0
b. Labor	1,350,000		0
c. Materials	556,200		0
Subtotal	4,156,200		0
2. Equipment Costs			
✓ Installed	2,088,000		0
__ Purchased			
3. Land and Site Development			
a. Equipment	720,000		0
b. Labor	360,000		0
c. Materials	95,400		0
Subtotal	1,175,400		0
4. Buildings and Services			
a. Equipment	319,500		0
b. Labor	1,017,000		0
c. Materials	697,500		0
Subtotal	2,034,000		0
5. Relocation Costs	0		0
Subtotal	0		0
6. Disposal Costs	90,000		0
Subtotal	90,000		0
TOTAL DIRECT COSTS	9,543,600		0
INDIRECT CAPITAL COSTS			
1. Engineering and Design	756,288	8% of direct cost	0
2. Contingency Allowance	1,607,112	17% of direct cost	0
3. Other Indirect Costs			
a. Legal fees	—	included in item 1.	
b. License/permit Costs	—		
c. Start-up & Shake-down	—		
Subtotal	—		
TOTAL INDIRECT COSTS	2,363,400		0
TOTAL CAPITAL COSTS	11,907,000		0

3.5.2 Operation and Maintenance Costs

Annual operating costs were estimated for the plume abatement and treatment facilities as follows:

- o Operating labor and materials
  - personnel ($50,000)
  - treatment chemicals ($834,000)
- o Maintenance materials and labor ($31,000)
- o Power ($32,000).

The total estimated O&M costs are $947,000 annually. Figure 3-11 presents a summary of these costs in the Annual Operation and Maintenance Costs Worksheet (Figure 3-5).

3.5.3 Annual Expenditures

Annual expenditures were calculated using the information presented in Figures 3-10 and 3-11 and summarized in the example Worksheet 4, Present Worth Analysis Worksheet, shown in Figure 3-12. These data would then also be entered on the example Worksheet 5, Summary of Cost Analysis, as shown in Figure 3-13, to facilitate comparison with other alternatives.

3.5.4 Present Worth Analysis

Present worth analysis for a 30 year period results in a sum of $20,833,000 as shown in Figure 3-12. A discount rate of 10% was assumed for this analysis. Capital costs were assumed to be incurred for year 0 of the analysis, while operation and maintenance costs were assumed for years 1 through 30.

3.5.5 Sensitivity Analysis

Sensitivity of the estimated costs for this alternative are evaluated for the major cost items (those costing more than $1,000,000 in this case) including replacing public water supply wells, providing transmission mains, constructing plume treatment facility, and constructing a slurry wall to surround the landfill area.

Estimated construction costs for water supply wells and water transmission mains are based on the estimator's extensive experience in these technologies and thus may range from +20% to -10% of estimated costs. Therefore, costs for water supply wells may range from $1,403,325 to $1,701,000 and costs for water transmission may range from $2,008,800 to $2,678,400.

FIGURE 3-11.

WORKSHEET 3: ANNUAL OPERATING COSTS (EXAMPLE)

Cost Component	Estimate($)	Basis of Estimate	Frequency	Year/ Period
O & M Costs				
1. Operating Labor				
a. Labor	$50,000		Annually	1-30
b.				
c.				
2. Maintenance Materials and Labor				
a. well regeneration & maintenance	$31,000		Annually	1-30
b.				
c.				
3. Auxiliary Materials and Labor				
a. Power	$32,000		Annually	1-30
b. Treatment chemicals	$834,000		Annually	1-30
c.				
4. Purchased Services				
a.				
b.				
c.				
5. Administration				
6. Insurance, Taxes, Licenses				
a.				
b.				
c.				
7. Maintenance Reserve and Contingency Costs				
8. Other				

FIGURE 3-12. WORKSHEET 4: COST ANALYSIS WORKSHEET (EXAMPLE)

Cost Component	Cost/Year Cost Occurs (Thousands of Dollars)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Capital Costs	11,907															
2. O&M Costs	X	947	→	→	→	→	→	→	→	→	→	→	→	→	→	→
3. Annual Expenditures, x_t (Sum of Lines 1 and 2)	11,907	947	→	→	→	→	→	→	→	→	→	→	→	→	→	→
4. Discount Factors Annual Discount Rate = 10 %	1.00	.909	.826	.751	.683	.621	.564	.513	.467	.424	.386	.350	.319	.290	.263	.239
5. Present Worth (Product of Lines 3 and 4)	11,907	861	782	711	647	588	534	486	442	402	366	331	302	275	249	226

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
1. Capital Costs																
2. O&M Costs	947	→	→	→	→	→	→	→	→	→	→	→	→	→	→	
3. Annual Expenditures, x_t (Sum of Lines 1 and 2)	947	→	→	→	→	→	→	→	→	→	→	→	→	→	→	Total Present Worth ($1000)
4. Discount Factor Annual Discount Rate = 10 %	.218	.198	.180	.164	.149	.135	.125	.112	.101	.092	.084	.076	.069	.063	.057	
5. Present Worth (Product of Lines 3 and 4)	206	188	170	155	141	128	116	106	96	87	80	72	65	60	54	20,833

FIGURE 3-13. WORKSHEET 5: SUMMARY OF COST ANALYSIS (EXAMPLE)

Cost Factor		Remedial Action Alternatives Costs					
		1. Example	2.	3.	4.	5.	6.
Capital Costs ($)		11,907 (Year 0)					
Present Worth ($)		20,833					
Annual Costs ($/Years)	1	947					
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
	13						
	14						
	15						
	16						
	17						
	18						
	19						
	20						
	21						
	22						
	23						
	24						
	25						
	26						
	27						
	28						
	29						
	30	↓					

Estimated costs for the plume treatment facility were based on reasonably accurate vendor quotes and may vary between +15% and -5% of estimated costs. Therefore, costs may range from $2,505,150 to $3,032,550.

Construction costs for slurry walls are highly variable because of site-specific problems and the 130 foot depth of the wall in this example and may range from +60% to -20% of the estimated cost. Therefore, costs may range from $1,664,280 to $3,965,760.

Two other factors tested are the effective life of the slurry wall and O&M costs. Experience with long-term performance of slurry walls at hazardous waste sites is limited, and it is not certain what the effective life of a slurry wall will be. The sensitivity analysis, therefore, examines the possibility that major portions of the slurry wall will have to be replaced after fifteen years (i.e., in year 16), at a cost of $1.5 million.

Finally, in the O&M category, treatment chemicals account for 88% of total O&M cost. Expenditures on treatment chemicals total $16,680,000 over the life of the remedial action, the largest single category of expenditures. Using historical data, real (inflation-adjusted) costs of treatment chemicals were seen to vary in a range of -10% to +20% of the estimated value. The sensitivity analysis, therefore, examines the effect of the low and high ends of this range on total costs.

Figures 3-14 and 3-15 show completed Worksheets 6 and 7 for the sensitivity analysis. The example Worksheet 6, Sensitivity Factors (Figure 3-14), explains the variables tested, the justification for testing them, the range over which they were tested, and the justification for the choice of range. The example Worksheet 7, Sensitivity Analysis (Figure 3-15), displays the results of the analysis. Results range from a best case of $18,745,000 to a worst case of $26,167,000 in present values.

FIGURE 3-14. WORKSHEET 6: SENSITIVITY FACTORS (EXAMPLE)

Sensitivity Factor	Justification for Consideration	Range	Justification for Range
1. Capital Cost			
a) water supply wells	cost > $1,000,000	-10% +20%	Experienced estimator Established technology
b) water supply transmission	cost > $1,000,000	-10% +20%	Experienced estimator Established technology
c) plume treatment facility	cost > $1,000,000	-5% +15%	Vendor quote Established technology
d) slurry wall	cost > $1,000,000	-20% +60%	Relatively new technology; uncertain site characteristics
2. Effective Life			
a) slurry wall	cost > $1,000,000 experience with slurry walls is limited at hazardous waste sites, making estimation of effective life difficult	up to $1.5 million	Cost of wall is estimated at $2.7 million; significant portions may need replacement after 10 years
3. O&M Cost			
a) treatment chemicals	cost > $1,000,000	-10% +20%	Historical cost variation

FIGURE 3-15. WORKSHEET 7: SUMMARY OF SENSITIVITY ANALYSIS (EXAMPLE)

Cost Factor		Baseline Cost	Sensitivity Factor Examined / Results					
			1. Lower capital cost	2. Higher capital cost	3. Replace slurry wall	4. +20% operating materials	5. −10% operating materials	6. Best case (LFS)
Capital Costs ($): (x1000) Year 0		11,907	10,684	16,651	13,371	11,817	11,817	10,684
Present Worth ($): (x1000)		20,833	19,556	25,051	22,294	22,579	19,983	18,745
Annual Expenditures ($/Years x 1,000)	1	947	947	947	947	1,114	859	859
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16				2,447			
	17				947			
	18							
	19							
	20							
	21							
	22							
	23							
	24							
	25							
	26							
	27							
	28							
	29							
	30	↓	↓	↓	↓	↓	↓	↓

FIGURE 3-15. WORKSHEET 7: SUMMARY OF SENSITIVITY ANALYSIS (EXAMPLE) (Continued)

Cost Factor		Baseline Cost	Sensitivity Factor Examined: Results					
			7. Worst Case (2,3,4)					
Capital Costs ($): (x1000) Year 0			18,151					
Present Worth ($): (x1000)			26,167					
Annual Expenditures ($/Years x 1,000)	1		1,114					
	2		↑					
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16							
	17							
	18							
	19							
	20							
	21							
	22							
	23							
	24							
	25							
	26							
	27							
	28							
	29							
	30		V					

REFERENCES

1. U.S. Environmental Protection Agency, Compendium of Costs of Remedial Technologies at Hazardous Waste Sites, January, 1984 In Print.

2. Perry, Robert H., and Cecil H. Chilton (eds.), Chemical Engineers Handbook, McGraw-Hill Book Company, New York, New York, 1973.

3. U.S. Environmental Protection Agency, A Standard Procedure for Cost Analysis of Pollution Control Operations, EPA-600/8-79-018, June 1979.

4. Robert Snow Means Company, Inc., Building Construction Cost Data 1983, Kingston, Mass., 1983.

5. McGraw-Hill Information Systems Company, Dodge Guide, New York, New York, 1981.

6. U.S. Office of Management and Budget, Circular No. A-94, revised 3/27/82.

7. U.S. Environmental Protection Agency, Preparing a Facility Plan, MCD-46, revised May 1975.

8. Grant, Eugene L., and Ireson, W. Grant, Principles of Engineering Economy, The Ronald Press Company, New York, New York, 1970.

9. American Heritage Publication Co., Inc. and Houghton Mifflin Co., The American Heritage Dictionary of the English Language, New York, New York, 1970.

10. Completed Scenario Bid Packages--Costs of Remedial Actions of Uncontrolled Hazardous Waste Sites, USEPA, In Print.